FINE-ROOT BIOMASS AND MORPHOLOGY IN SCOTS PINE *PINUS SYLVESTRIS* L. YOUNG STANDS

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Abstract

In the summer 2010, a study of the below-ground biomass of young (12 - and 14-year-old) Scots pine *Pinus sylvestis* L. stands was carried out in central Latvia. The fine-root (diameter < 2 mm) biomass, tips, length and volume were determined for the mineral soil layer (0 – 60 cm) by core sampling. The main objective was to determine the average fine-root biomass and morphological characteristics in different classes of young stands of Scots pines. The mean fine-root biomass was calculated for the whole stand by using below-ground biomass measurements of different components of sample trees and measurement of the tree stand. The amount of dry fine-root biomass in the soil layer was 5.3 ± 1.6 t ha^{-1} in the 14-year-old stand and 3.6 ± 1.5 t ha^{-1} in the 12-year-old stand. The study showed that the largest portion (52%) of the total fine-root biomass of 12 - and 14-year-old Scots pine stands was located at a depth of 0–10 cm, decreasing in deeper mineral soil layers. The average morphological characteristics of fine roots were higher in the older stand. Analysis of the morphology of fine roots showed that at soil depth of 0 – 10 cm the mean root length was 233 ± 44 cm, volume – 1.3 ± 0.6 cm^3, value of tips – 537 ± 104 and diameter – 0.7 ± 0.1 mm per 100 cm^{-3}.

Key words: fine roots, *Pinus sylvestris*, biomass, soil layer, morphological characteristics

Introduction

The world forests contain 80% of all above-ground carbon and 40% of all below-ground carbon (Dixon et al., 1994). Fine roots are the most significant components contributing to carbon cycling in forest ecosystems. Up to approximately 75% of the annual net primary production can be allocated to fine roots (Gill and Jackson, 2000). Thus, fine roots play a key role in forest ecosystem carbon and nutrient cycling and accumulation.

Fine roots are non-woody, small-diameter roots and their associated mycorrhizae, and they are important for the water and nutrients uptake of the forest (Finer et al., 2011). Fine roots are significant for taking up water and nutrients from soil, and environmental factors such as air temperature, soil acidity, precipitation and nutrient availability in soil affect the functioning of the roots. Thus, the distribution and development parameters of fine roots in soil layers determine the above-ground vitality and productivity of trees (Jackson et al., 1996; Vogt et al., 1996).

The average fine-root biomass has proven to be smaller in boreal forests (in cooler climatic conditions) than in temperate and tropical forests (in warmer climatic conditions) (Jackson et al., 1996). The fine-root biomass differences between boreal and temperate to tropical forests depended on the availability of water and nutrients. Many experiments have shown that the fine-root biomass in boreal and temperate forests increases along with precipitation; root biomass correlates with the availability of soil nutrients and amount of water, and it has usually been smaller in the same geographical area when the availability of nutrients is higher (Vogt et al., 1996; Finer and Laine, 1998; Helmisaari et al., 2007) or water availability is poorer (Leuschner et al., 2004; Meier and Leuschner, 2008).

Morphological plasticity of fine roots has been proposed as a mechanism by which plants respond to variation in soil nutrient supply (Hodge, 2004; Lõhmus et al., 1989). Alterations in fine-root morphological traits reflect exploitation of water and nutrients in the soil. The most frequently-measured functionally important morphological indicators of fine roots are root length, root area, and root density, which are believed to be indicative of environmental changes.

Relatively few studies have been carried out on fine root biomass production and morphology characteristics in relation to stand age. In this study, the main objective was to determine the average fine-root biomass and morphological characteristics in different classes of young stands of Scots pines.

Materials and Methods

Experimental stands

The research was carried out in two young stands of Scots pine, established on a former agricultural lands in central Latvia, Ozolnieki region. The stands represent different age groups – 12 and 14 years (Table 1). One experimental plot (500 m^2) in each stand was established in the summer 2010. The plots are not replicated, but therefore statistical analysis (descriptive statistics) of the data between stand age years is used. The stands were situated on a similar site and soil type.

In both Scots pine stands there was sandy loam soil, with a relatively smaller humus layer, but saturated with nutrients. The site type according to classification is *Hylocomiosa* (Bušs, 1981).

Table 1

Same characteristics of the research stands

Characteristics	Stand age years	
	12	14
Plot area (m^2)	500	500
Numbers of trees (per ha)	2145	2925
Mean diameter (cm)	11.2	10.3
Mean height (m)	7.7	8.2
Basal area (m^2 ha^{-1})	21.0	24.3
Stand volume (m^3 ha^{-1})	92.2	115.4

Fine roots sampling

Root sampling was conducted in August 2010. The soil core sampling method was used to collect fine roots (diameter ≤ 2.0 mm). Twenty soil cores (volumetric samples 100 cm^3 and core diameter 50 mm) per sampling were randomly taken in both sample plots for determination of the fine-root biomass. The soil cores were divided into five layers by depth: 0 – 10 cm, 11 – 20 cm, 21 – 30 cm, 31 – 40 cm and 51 – 60 cm of the mineral soil. The samples were placed in polyethylene bags, transported to the laboratory, and stored in a refrigerator at 4 °C until the analysis.

Laboratory analysis

In the laboratory, the roots were washed and separated into Scots pine roots and roots of other plants. Small and coarse roots (diameter > 2 mm) were excluded from the analysis.

Fine roots are generally defined as nonwoody, small-diameter roots (Nadelhoffer and Raich, 1992), but there is no established convention defining the diameter-size range of fine roots (Fogel, 1983). In this study, roots smaller than 2 mm were regarded as fine roots.

The morphology indices of *Pinus sylvestris* fine roots were analyzed by using the digital image analysis system WIN-Rhizo 2002c (Regents instruments, QC, Canada). The roots were placed in a transparent box filled with water (to facilitate root visibility) on a scanner. The image analysis software scanned all the fine root fragments and calculated morphological parameters, such as root length, and number of root tips. After scanning, the separated fine roots were dried at 105 °C until reaching constant weight, and weighted to determine the dry biomass. Based on the results, the following average morphological indices were calculated: root length, root volume, root diameter, root tip density and biomass at soil layer depth of 0 – 10 cm, 11 – 20 cm, 21 – 30 cm, 31 – 40 cm, 41 – 50 cm and 51 – 60 cm.

Results and Discussion

Fine root biomass

The amount of fine-root biomass varied between soil layers. A major portion of the Scots pine fine roots (46%) was found in the upper mineral soil immediately below the humus layer (Helmisaari et al., 2002). There was significant prevalence of fine-root biomass in the top soil layers, decreasing at greater soil depth (Claus and George, 2005; Makkonen and Helmisaari, 1998; Fujii and Kasuya, 2008; Helmisaari et al., 2002). C. Trettin et al. has noted that roots allow for efficient uptake of water and nutrients from the surface layers of soil (Trettin et al., 1999). Our 12 - and 14-year-old stands had dry fine-root biomass of 1.8 ± 0.5 t ha^{-1} (52%) and 2.7 ± 0.4 t ha^{-1} (52%) in the upper mineral soil (0 – 10 cm), which is nearly equal to the fine root biomass range reported by other authors. The investigations showed that there was a clear relation between the average fine-root biomass of a stand and the depth of the mineral soil layer, which is described by the coefficient of determination R^2=0.89 (Figure 1). The vertical distribution of the fine root biomass of both Scots pine stands decreased with increased soil depth. The main fine-root biomass of 12 - and 14-year-old Scots pine stands was located at a depth of 0 – 10 cm, decreasing in deeper mineral soil layers.

There were significant differences between the soil layers and average fine-root biomass in the Scots pine stands ($p<0.05$) (Figure 2). The distribution of fine-root biomass in soil layer 0 – 60 cm was higher in the older stand (14-year-old) – dry biomass 5.3 ± 1.6 t ha^{-1}; in the younger stand (12-year-old) – dry biomass 3.6 ± 1.5 t ha^{-1}.

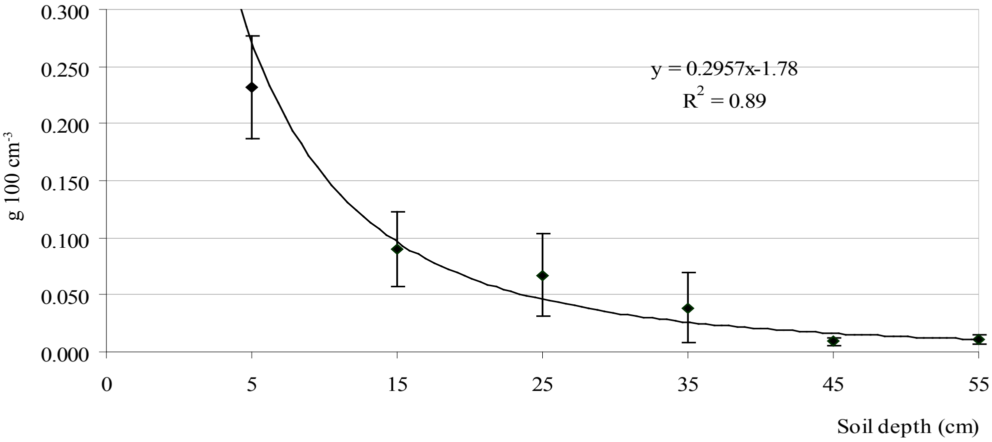

Figure 1. Average fine root biomass and its changes in the soil layer of 12 - and 14-year-old Scots pine stands.

The average dry fine-root biomass of 12 - and 14 – year - old Scots pine stands at a depth 0 – 10 cm is 2.3 ± 0.4 t ha^{-1}, but decreases in deeper mineral soil layers: at a depth of 10 – 20 cm – 0.9 ± 0.3 t ha^{-1}, at a depth of 20 – 30 cm – 0.7 ± 0.3 t ha^{-1}, at 30 – 40 cm – 0.4 ± 0.3 t ha^{-1}, at 40 – 50 cm – 0.1 ± 0.03 t ha^{-1}, and at 50 – 60 cm – 0.1 ± 0.04 t ha^{-1}.

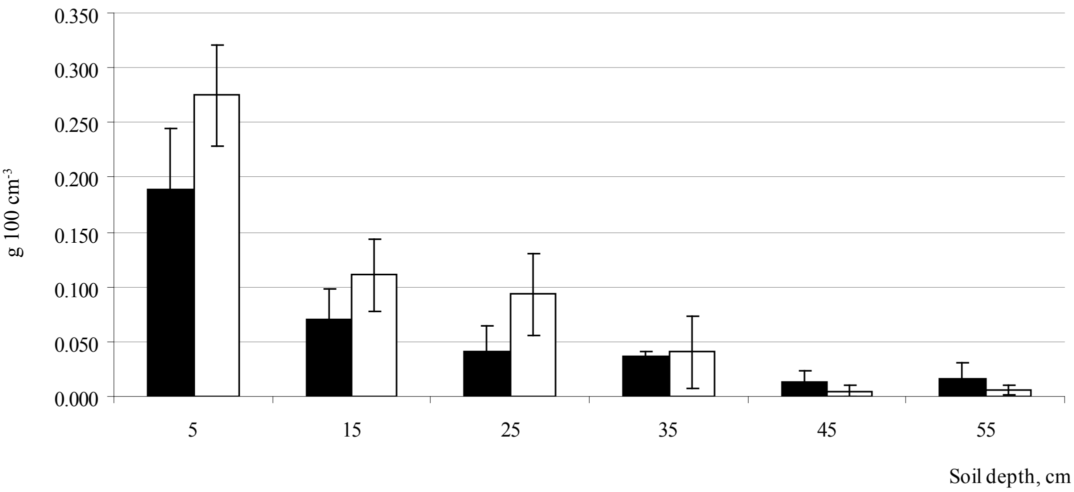

Figure 2. Comparison of fine-root biomass in the different soil depths of 12 - and 14-year-old Scots pine stands: ■ 12 years, □ 14 years.

Fine root morphology

The depth distribution of morphological characteristics of fine roots varied with stand age (Makkonen and Helmisaari, 2001). The fine root length, density and volume in the surface soil layer were higher than at a greater soil depth. The fine root morphology showed marked distinctions between the Scots pine stands, but these root morphology differences did not lead to significant differences ($p>0.05$) in the fine root length, volume, and diameter or root tip (Figure 3).

The average morphological characteristics of fine roots were higher in the older stand, but there were no significant differences between the young Scots pine stands in terms of fine root morphology. The analysis of fine root morphology showed that at soil depth of 0 – 10 cm the mean root length was 233 ± 43 cm, volume – 1.3 ± 0.6 cm^3, value of tips – 537 ± 104, and diameter – 0.7 ± 0.1 mm per 100 cm^{-3}.

Except for the deepest roots, the mean diameters of all fine roots ranged between 0.7 and 0.6 mm in the upper layers. Roots in the upper 30 cm of soil were, on average, thicker than roots at a depth of 30 – 60 cm (0.7 ± 0.02 versus 0.4 ± 0.1 mm). These values are slightly larger than those reported by J. Roberts for a *Pinus sylvestris* L. stand: 0.28 mm in the first 15 cm (Roberts, 1976).

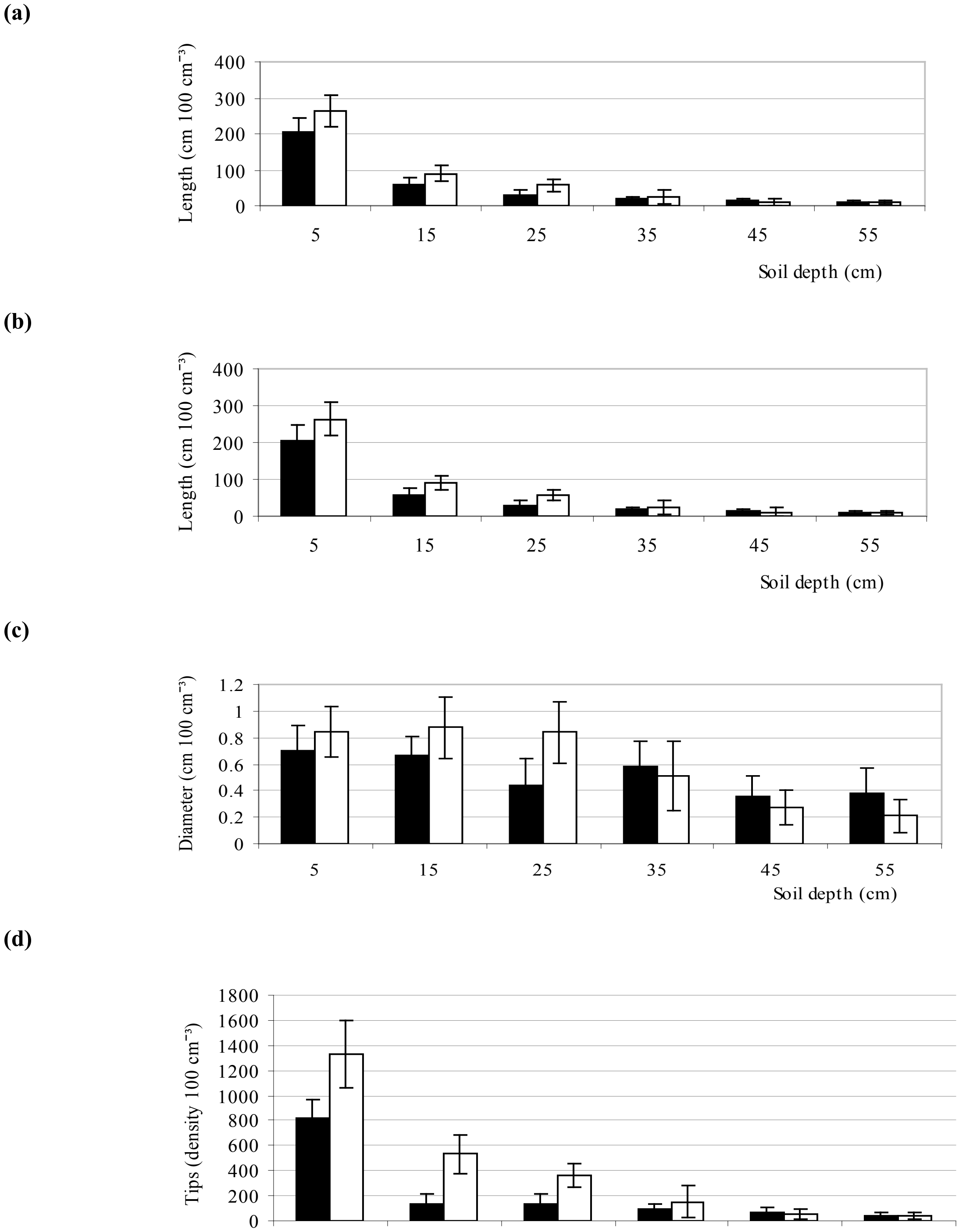

Figure 3. Average morphological characteristics (**a** root length, **b** root volume, **c** root diameter, **d** root tip density) of fine roots in young stands of Scots pine: ■ 12 years, □ 14 years.

Conclusions

The vertical distribution of the fine root biomass of the Scots pine stands decreased with increased soil depth. The largest part of the fine-root biomass is located in the upper mineral soil layers (0 – 10 cm). The dry fine-root biomass in 12- and 14-year-old Scots pine stands had 1.8 ± 0.5 t ha^{-1} and 2.7 ± 0.4 t ha^{-1} in the upper mineral soil (0 – 10 cm).Total fine-root biomass in soil layer 0 – 60 cm was higher in the older stand (14-year-old) – dry biomass 5.3 ± 1.6 t ha^{-1}; in the younger stand (12-year-old) – dry biomass 3.6 ± 1.5 t ha^{-1}. The mean morphological indicators of the fine roots were higher in the 14-year-old stand than in the 12-year-old stand.

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